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ABSTRACT

The Nature of Scientific Knowledge Scale (NSKS) is a 48 item, Likert-type instrument designed to assess high school students' understanding of the nature of scientific knowledge. This attitude scale is based on a six-factor model adapted from the factor-explication format used by Victor Showalter. Scientific knowledge is characterized as: (1) amoral, i.e., provides people with many capabilities, but does not provide instruction on how to use them; (2) creative, i.e., is a product of human intellect; (3) developmental, i.e., is never "proven" in the absolute and final sense; (4) parsimonious, i.e., tends toward simplicity but not to the exclusion of complexity; (5) testable, i.e., is capable of public empirical test; and (6) unified, i.e., is born out of an effort to understand the unity of nature. When the NSKS was administered to high school and college students, the reliability ranged from .65 to .89. The construct validity of the NSKS was examined by testing an anticipated difference in understanding of the nature of scientific knowledge between two groups of college freshmen with different educational backgrounds. The students who had previously studied philosophy of science had higher mean scores on five of the six NSKS subscales and on the entire NSKS. The scale and instructions for scoring are appended. (MV)

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USERS' MANUAL

for the

NATURE OF SCIENTIFIC KNOWLEDGE SCALE

Peter A. Rubba Jr.

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USERS' MANUAL
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NATURE OF SCIENTIFIC KNOWLEDGE SCALE

by

Peter A. Rubba Jr.

The Nature of Scientific Knowledge Scale (NSKS) is a 48 item, six subscale, Likert type research instrument designed to assess high school students' understanding of the nature of scientific knowledge. The instrument was developed during the course of doctoral research at the Indiana University School of Education. This manual describes instrument rationale, development process, reliability and validity evidence, scoring procedures and possible applications for the NSKS.*

Rationale for the NSKS

The argument for science education for effective citizenship has been enumerated over the past two centuries by scientists, science educators and a variety of commissions and committees. In the past two decades the term scientific literacy has come to be used for the concept behind the argument. Today, scientific literacy is generally acknowledged among science educators as a major purpose of science instruction in our schools. Unfortunately, we lack instrumentation to evaluate science instructional efforts for scientific literacy.

The development of instruments to assess scientific literacy has been held up by the lack of an objective definition of scientific literacy. There have been a number of attempts at formally defining scientific literacy in the recent past. Most of the definitions, however, have been limited by their use of intransitive verbs which do not set forth observable states. As a result, definitions of scientific literacy have not specified observable behaviors which characterize one who is scientifically literate.

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*For a complete description of NSKS development see, Rubba, P.A. The development, field testing and validation of an instrument to assess secondary school students' understanding of the nature of scientific knowledge. Unpublished doctoral dissertation, Indiana University, 1977.

In 1974, Victor Showalter and his colleagues at the Center for Unified Science Education in Columbus, Ohio, produced the first objective definition of scientific literacy. After a review of 15 years of relevant literature, Showalter composed a seven dimension definition of scientific literacy. Each of the dimensions of scientific literacy was described by listing and characterizing factors which comprise it. The statement and explication of the dimension factors detailed the nature of each of the seven dimensions in Showalter's definition of scientific literacy, providing a succinct statement of educational expectation against which instructional efforts in the area of scientific literacy can be measured.

The first dimension of the Showalter definition stated, "the scientifically literate person understands the nature of scientific knowledge." (p. 2) The Nature of Scientific Knowledge Scale (NSKS) was developed to assess this dimension of the Showalter definition of scientific literacy among high school students.

Development of the NSKS

The development of the NSKS took place in seven steps. Those steps are outlined below.

Step 1: Establishing a Model of the Nature of Scientific Knowledge

Showalter listed nine factors under the first dimension of scientific literacy. A preliminary study of the factors revealed several of them to be overlapping. After a review of the literature on the nature and philosophy of science, a six factor model of the nature of scientific knowledge was constructed following the factor-explication format used by Showalter. The model was then submitted to three philosophers of science for review. Each of the philosophers of science endorsed its validity.

The nature of scientific knowledge was characterized by the following six factors and their explications.

Amoral	Scientific knowledge provides man with many capabilities, but does not instruct him on how to use them. Moral judgment can be passed only on man's application of scientific knowledge, not on the knowledge itself.

Showalter, V. What is unified science education? (part 5) program objectives and scientific literacy. Prism II, Spring, 1974.

Creative	Scientific knowledge is a product of the human intellect. Its invention requires as much creative imagination as does the work of an artist, a poet or a composer. Scientific knowledge embodies the creative essence of the scientific inquiry process.
Developmental	Scientific knowledge is never "proven" in an absolute and final sense. It changes over time. The justification process limits scientific knowledge as probable. Beliefs which appear to be good ones at one time may be appraised differently when more evidence is at hand. Previously accepted beliefs should be judged in their historical context.
Parsimonious	Scientific knowledge tends toward simplicity, but not to the distain of complexity. It is comprehensive as opposed to specific. There is a continuous effort in science to develop a minimum number of concepts to explain the greatest possible number of observations.
Testable	Scientific knowledge is capable of public empirical test. Its validity is established through repeated testing against accepted observations. Consistency among test results is a necessary, but not a sufficient condition for the validity of scientific knowledge.
Unified	Scientific knowledge is born out of an effort to understand the unity of nature. The knowledge produced by the various specialized sciences contribute to a network of laws, theories and concepts. This systematized body gives science its explanatory and predictive power. (Rubba, 1976)

Step 2: Item Pool Preparation

In accordance with the view that each dimension of the Showalter definition of scientific literacy represents a continuum along which individuals can make progress in their degree of scientific literacy, a Likert type attitude scale was selected as the instrument type to be developed. Twelve to fourteen positive affect item statements, and the same number of negative affect item statements, were written for each of the six factors in the model of the nature of scientific knowledge. Care was taken in writing the item statements to make them science content general, to use simple wording and to eliminate statement ambiguity. A set of criteria for writing attitude statements was consulted for the latter.

Step 3: First Item Refinement--Reading Level

The developer wanted to keep the reading level of the items at the junior high level. Because reading level formulas could not be applied to individual items, the reading level of the item statements was checked by having nine sixth graders of comparable reading ability read the item statements aloud. Substitute words and phrases were found for those stumbled on, mispronounced or stated as not being understood by at least six of the students. A few items were dropped.

Step 4: Second Item Refinement--Form and Content

The sixty-two item statements pairs which survived, were submitted to ten science education doctoral students for evaluation. The graduate students considered item science content generality, clarity and correspondence to respective factors in the model of the nature of scientific knowledge. Fifty-seven item statement pairs survived the process.

Step 5: Third Item Refinement--A Tryout

The item statements were each attached to a five point Likert type scale labelled "strongly agree," "agree," "neutral," "disagree," "strongly disagree," and randomly arranged as a tryout instrument. The tryout instrument was administered to a group of 31 high science ability high school juniors. An open discussion of the items was held with the students immediately following the administration of the instrument. All 114 items survived the procedure, though changes were made to a few items.

Step 6: Item Selection Panel--Judged Content Validity

The content validity of the item statements was judged against the model of the nature of scientific knowledge by a panel of nine experts. The panel was composed of two philosophers of science, two science educators, two scientists (one from the life sciences and one from the physical sciences), two experienced high school science teachers (one who taught life science and one who taught physical science) and a psychometrician. After two rounds of critiquing and revising items, 36 positive and 36 negative affect item statements were judged by at least seven of the panel members to measure its respective factor in the model of the nature of scientific knowledge.

Step 7: Field Testing and Item Selection

The 72 items which were judged content valid were each attached to a five point Likert scale and randomly arranged as a tryout instrument. The tryout instrument was administered to the 674 students in five science courses at a high school in the mid-west.

The discriminating quality of each item was identified by calculating an item to subscale (one per model factor) score correlation for it. Coefficient alpha reliability functions were then averaged for various sized instruments composed of equal numbers of positive and negative items. The highest instrument mean subscale coefficient alpha reliability was obtained with the four positive and four negative items with the highest item to subscale score correlations in each subscale. These 48 items were randomly arranged to form the Nature of Scientific Knowledge Scale (NSKS). The NSKS contains six subscales, one for each factor in the model of scientific knowledge.

NSKS Reliability

The reliability of the NSKS was assess during its development and in a subsequent study with samples of students in grades 9 through 16. A description of the samples and the respective coefficient alphas, r_{kk}, are listed in figure 1.

Sample	n	r_{kk}
Grade 9 General Science	101	0.65
Grade 9-10 Biology	311	0.74
Grade 10-11 Chemistry	111	0.74
Grade 11-12 Physics	36	0.77
Grade 12 Advance Chemistry	36	0.89
College Freshmen (nonscience majors)	194	0.80
College Students	160	0.88

Figure 1.

NSKS Construct Validity

The content validity of the NSKS items was judged by a panel of experts during the sixth step of its development. The construct validity of the NSKS was examined after its development by testing an anticipated difference in understanding of the nature of scientific knowledge between two groups of college freshmen due to differences in their instructional backgrounds.

An ex post facto research design was used to collect evidence of NSKS construct validity. Forty freshmen in an introductory philosophy of science course and who had completed at least one college science course, were expected to understand the nature of scientific knowledge better than 125 freshmen at the same university with no formal history and philosophy of science background who were enrolled in a biology course for nonscience majors. The mean scores of the two groups on the six subscales of the NSKS and on the entire instrument were compared using t-tests.

The group of freshmen who had studied philosophy of science had higher mean scores on five of the six NSKS subscales, all except the creative subscale, and on the entire NSKS. The developmental, parsimonious, testable and unified mean subscale scores and the entire NSKS mean scores for this group were found to be significantly higher at the 0.05 level. No serious differences were shown to exist between the two groups on the extraneous variables of sex, age, number of high school science courses taken and semester hours of college science taken.

NSKS Scoring

The NSKS can be broken into six subscales, one for each factor in the model of the nature of scientific knowledge. Each subscale contains four positive items and four negative items. The item to subscale key is listed in Figure 2.

NSKS Subscale	Positive Item Numbers	Negative Item Numbers
Amoral	4, 5, 8, 48	7, 18, 21, 36
Creative	17, 20, 28, 32	1, 23, 34, 41
Developmental	16, 26, 37, 42	25, 27, 31, 43
Parsimonious	2, 6, 29, 46	14, 15, 39, 40
Testable	12, 22, 38, 45	9, 11, 13, 33
Unified	3, 30, 35, 47	10, 19, 24, 44

Figure 2.

Because computer answer sheets differ in format from computer system to computer system, a computer scoring program could not be written for the NSKS. A hand scoring answer sheet is reproduced on the next page. To the left of each item number is a blank space into which an item point value may be placed. These spaces are labelled with small letters which identify the subscale to which the item belongs, and whether the item is positive or negative, e.g., a=positive amoral item, na= negative amoral item.

Name_____

Directions: Place a "X" over one response per item according to the following code:

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
SA	A	N	D	SD

nc_____	1	SA	A	N	D	SD	nd_____	25	SA	A	N	D	SD
p_____	2	SA	A	N	D	SD	d_____	26	SA	A	N	D	SD
u_____	3	SA	A	N	D	SD	nd_____	27	SA	A	N	D	SD
a_____	4	SA	A	N	D	SD	c_____	28	SA	A	N	D	SD
a_____	5	SA	A	N	D	SD	p_____	29	SA	A	N	D	SD
p_____	6	SA	A	N	D	SD	u_____	30	SA	A	N	D	SD
na_____	7	SA	A	N	D	SD	nd_____	31	SA	A	N	D	SD
a_____	8	SA	A	N	D	SD	c_____	32	SA	A	N	D	SD
nt_____	9	SA	A	N	D	SD	nt_____	33	SA	A	N	D	SD
nu_____	10	SA	A	N	D	SD	nc_____	34	SA	A	N	D	SD
nt_____	11	SA	A	N	D	SD	u_____	35	SA	A	N	D	SD
t_____	12	SA	A	N	D	SD	na_____	36	SA	A	N	D	SD
nt_____	13	SA	A	N	D	SD	d_____	37	SA	A	N	D	SD
np_____	14	SA	A	N	D	SD	t_____	38	SA	A	N	D	SD
np_____	15	SA	A	N	D	SD	np_____	39	SA	A	N	D	SD
d_____	16	SA	A	N	D	SD	np_____	40	SA	A	N	D	SD
c_____	17	SA	A	N	D	SD	nc_____	41	SA	A	N	D	SD
na_____	18	SA	A	N	D	SD	d_____	42	SA	A	N	D	SD
nu_____	19	SA	A	N	D	SD	nd_____	43	SA	A	N	D	SD
c_____	20	SA	A	N	D	SD	nu_____	44	SA	A	N	D	SD
na_____	21	SA	A	N	D	SD	t_____	45	SA	A	N	D	SD
t_____	22	SA	A	N	D	SD	p_____	46	SA	A	N	D	SD
nc_____	23	SA	A	N	D	SD	u_____	47	SA	A	N	D	SD
nu_____	24	SA	A	N	D	SD	a_____	48	SA	A	N	D	SD

a_____ p_____ nsks_____

c_____ t_____

d_____ u_____

In scoring the NSKS, the point value assignments shown in Figure 3 are to be made and placed in the blanks.

Response	Positive Item Values (a, c, d, p, t, u)	Negative Item Values (na, nc, nd, np, nt, nu)
SA	5	1
A	4	2
N	3	3
D	2	4
SD	1	5

Figure 3.

Subscale socres are calculated by adding the four positive and four negative items with the appropriate symbols. There are spaces to record these subscale scores at the bottom of the answer sheets. By summing these subscale scores, a NSKS score can be calculated and recorded on the bottom of the answer sheet. Following this scoring scheme, a maximum score of 40 points for each subscale and 240 points for the entire NSKS is possible.

Possible Applications for the NSKS

The NSKS was developed to assess understanding of the nature of scientifice knowledge among high school students. During development the NSKS also was shown to be a reliable measure with college students. The instrument might be useful in assessing the understanding of the nature of scientific knowledge of other populations, e.g., teachers, scientists, laymen.

The NSKS may be used in descriptive and in experimental studies. Norms have not been established on the instrument. Descriptive studies should thus include comparative groups. Pretest-posttest control group designs are recommended for experimental research investigating the effects of science instructional strategies, materials and programs on understanding the nature of scientific knowledge.

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Nature of Scientific Knowledge Scale

This instrument was developed in the course of research for the Doctor of Education degree at the School of Education, Indiana University, Bloomington, Indiana. © 1976, by Peter A. Rubba Jr.

NATURE OF SCIENTIFIC KNOWLEDGE SCALE

This instrument assesses your opinions about the nature of scientific knowledge.

Each of the statements in the instrument describes a view about scientific knowledge. You may agree with some of the statements; you may disagree with other statements; or your feelings about statements may be some degree of agreement or disagreement.

After you carefully read each statement, decide whether you strongly agree, agree, are neutral, disagree, or strongly disagree with it. Then, find the number of the statement on your answer sheet and blacken in the appropriate space with a pencil:

A strongly agree

B agree

C neutral

D disagree

E strongly disagree

Example Statement:

00. The term of office for the President of the United States should be increased to six years.

Answer Sheet:

00. A B C D E

(This individual agreed with the statement, and so blackened in the space below the letter B.)

Respond to the following statements in a similar manner. Blacken in only one space on the answer sheet for each statement. If you change your mind, erase your first mark completely.

PLEASE DO NOT MARK ON THIS TEST BOOKLET.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
A	B	C	D	E

1. Scientific laws, theories and concepts do not express creativity.
2. Scientific knowledge is stated as simply as possible.
3. The laws, theories and concepts of biology, chemistry and physics are related.
4. The applications of scientific knowledge can be judged good or bad, but the knowledge itself cannot.
5. It is incorrect to judge a piece of scientific knowledge as being good or bad.
6. If two scientific theories explain a scientist's observations equally well, the simpler theory is chosen.
7. Certain pieces of scientific knowledge are good and others are bad.
8. Even if the applications of a scientific theory are judged to be good, we should not judge the theory itself.
9. Scientific knowledge need not be capable of experimental test.
10. The laws, theories and concepts of biology, chemistry and physics are not linked.
11. Consistency among test results is not a requirement for the acceptance of scientific knowledge.
12. A piece of scientific knowledge will be accepted if the evidence can be obtained by other investigators working under similar conditions.
13. The evidence for scientific knowledge need not be open to public examination.
14. Scientific laws, theories and concepts are not stated as simply as possible.
15. There is an effort in science to build as great a number of laws, theories and concepts as possible.
16. We accept scientific knowledge even though it may contain error.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
A	B	C	D	E

17. Scientific knowledge expresses the creativity of scientists.

18. Moral judgement can be passed on scientific knowledge.

19. The laws, theories and concepts of biology, chemistry and physics are not related.

20. Scientific laws, theories and concepts express creativity.

21. It is meaningful to pass moral judgement on both the applications of scientific knowledge and the knowledge itself.

22. The evidence for scientific knowledge must be repeatable.

23. Scientific knowledge is not a product of human imagination.

24. Relationships among the laws, theories and concepts of science do not contribute to the explanatory and predictive power of science.

25. The truth of scientific knowledge is beyond doubt.

26. Today's scientific laws, theories and concepts may have to be changed in the face of new evidence.

27. We do not accept a piece of scientific knowledge unless it is free of error.

28. A scientific theory is similar to a work of art in that they both express creativity.

29. There is an effort in science to keep the number of laws, theories and concepts at a minimum.

30. The various sciences contribute to a single organized body of knowledge.

31. Scientific beliefs do not change over time.

32. Scientific knowledge is a product of human imagination.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
A	B	C	D	E

33. The evidence for a piece of scientific knowledge does not have to be repeatable.

34. Scientific knowledge does not express the creativity of scientists.

35. Biology, chemistry and physics are similar kinds of knowledge.

36. If the applications of a piece of scientific knowledge are generally considered bad, then the piece of knowledge is also considered to be bad.

37. Scientific knowledge is subject to review and change.

38. Scientific laws, theories and concepts are tested against reliable observations.

39. If two scientific theories explain a scientist's observations equally well, the more complex theory is chosen.

40. Scientific knowledge is specific as opposed to comprehensive.

41. Scientific theories are discovered, not created by man.

42. Those scientific beliefs which were accepted in the past, and since have been discarded, should be judged in their historical context.

43. Scientific knowledge is unchanging.

44. Biology, chemistry and physics are different kinds of knowledge.

45. Consistency among test results is a requirement for the acceptance of scientific knowledge.

46. Scientific knowledge is comprehensive as opposed to specific.

47. The laws, theories and concepts of biology, chemistry and physics are interwoven.

48. A piece of scientific knowledge should not be judged good or bad.